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IP Address Management: Augmenting Sandia's Capabilities Through Open Source Tools

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IP Address Management: Augmenting Sandia's Capabilities Through Open Source Tools

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Abstract

Internet Protocol (IP) address management is an increasingly growing concern at Sandia National Laboratories (SNL) and the networking community as a whole. The current state of the available IP addresses indicates that they are nearly exhausted. Currently SNL doesn't have the justification to obtain more IP address space from Internet Assigned Numbers Authority (IANA). There must exist a local entity to manage and allocate IP assignments efficiently. Ongoing efforts at Sandia have been in the form of a multifunctional database application notably known as Network Information System (NWIS). NWIS is a database responsible for a multitude of network administrative services including IP address management. This study will explore the feasibility of augmenting NWIS's IP management capabilities utilizing open source tools. Modifications of existing capabilities to better allocate available IP address space are studied.

Table of Contents

List of Tables and Figures

Introduction

Internet Protocol (IP) address management affects Sandia National Laboratories and the rest of the globe as well (see Appendix A). IP address management has been largely handled by a SNL based entity known as Network Information System (NWIS). Despite their ongoing attempts at IP address management, SNL's IP address space is still wasted considerably (see Appendix B). The wasted space has been attributed to many factors that are beyond their control. Open source tools such as Northstar and FreeIPdb can give considerable insight in how SNL's IP address management system might be augmented to better manage its IP address space. Binary tree principles gained from these tools can help SNL manage its IP address space more efficiently. Although technical, the IP address space solution encompasses management as well. At SNL there doesn't exist a central entity that is responsible for managing its IP address space and seeing to it that it is not wasted. A lack of central management has allowed for uncoordinated IP addressing practices. This has made the task of improving SNL's IP address space more and more difficult the longer the issue has been neglected.

Organizational Requirements

A governing entity to oversee the thoughtful use of an address space is as important as the IP address management tool implemented. Implementing a set number of management principles is difficult because each organization is different. A few suggestions include, but are not limited to the following:

Centralized Management – Multiple entities in control of scarce resources may lead to conflict. Central management can allow for a standard practice for

Requests, Allocation, and Reclamation of resources. Questions to consider for management practices might include:

- **Requests**
    - Is the request warranted?
    - Is what has been issued being fully utilized?
    - What is the resource intended use?
    - What is the requester's priority?
- **Allocation**
    - Will the amount of IP address space provided be excessive?
    - What has been issued to the requester already?
    - Can similar allocations be classified together?
    - What is the potential growth of the allocation?
- **Reclamation**
    - If a large address space was originally given out and was deemed underutilized. The IP address space must be reclaimed and resized to conserve and extend the longevity of the remaining address space.
    - Reallocation of IP address space may be necessary to provide contiguous IP address allocation.

Trained Network Analysts – The team assigned to manage the IP address space should understand the technical aspects as well as resource management principles.

The ideas proposed are only suggestions. It is important that an organization develop in-house strategies to custom fit their needs. IP address management

requires both a technical and managerial solution for it to be most effective. Leaving out the managerial aspect will result in a system that is marginal at best.

Tool Specifications

The IP address management tool's specifications were based on the frequency of seeing a feature in open source and proprietary developers. Higher occurrences of features indicated that the given features were desirable as a whole. Lower occurrences indicated a feature was usually unique to that tool, or was not a major specification. These specifications were then coupled with the knowledge of network engineers at Sandia National Laboratories (SNL). The resulting compilation of specifications satisfied general IP address management specifications but were also tailored to meet the custom needs of SNL. The resulting specifications and a brief explanation of each specification are shown below.

- **Web Accessibility**
    - The tool must provide a means of easy access. A web interface will allow management/users direct interface from the internet.
- **Multi User Access**
    - Different levels of access must be implemented to segregate management from normal users. Management will have additional privileges hidden from normal users for administrative purposes.
- **IPv4 & IPv6 Support**
    - The tool should be able to subnet and keep track of assignments efficiently. The tool will also provide a means of Allocation, Requesting, and Reclaiming of IP address assignments.
- **Variable Length Subnet Masking (VLSM)**

    - VLSM will be supported. The tool will not allow address overlap indicate that address overlap has occurred.

- **Import/Export Data Efficiency**
    - The ability to Import and Export large subnet setups is required. Imported/Exported data should contain information such as the subnet, network mask, owner etc.
- **Resource Queries**
    - Users must have an easy way to query resource availability and information about the existing IP address allocation. The amount of information that can be gathered is limited by management.
- **Compatible with existing IP management tools**
    - Either the tool or its implemented algorithms must be able to function in conjunction with Network Information System (NWIS)
- **Easy to Use**
    - Should remain transparent to the end user.

Open Source Tool Selection: NorthStar vs. FreeIPdb

The choice to use open sources tools is outlined in Appendix C. NorthStar [6] was selected as the most favorable choice because it was the best written and very modular which made it easy to customize. Both NorthStar and FreeIPdb [7] were largely uncommented which made algorithm extraction difficult. Code analyses revealed the tools utilize a binary tree structure and were built on a similar database. If algorithm extraction were to take place in a reasonable amount of time, then NorthStar would be the best choice. The included table compares the tool requirements with the features provided. The unsupported features could potentially be implemented with slight code modification or direct database modifications.

Tool Requirements	NorthStar	FreeIPdb
Web Acessibility	✓	✓
Multi User Access	✓	✓
Both IPv4 & IPv6 Support	✗	✓
VLSM Support	✓	✓
Import/Export	✗	✓
Resource Queries	✓	✓
NWIS Compatible	✗	✗
Ease of Use	✓	✓

Figure 1 – NorthStar and FreeIPdb

Algorithms Employed by Northstar

Understanding the main algorithms used by NorthStar is necessary for integration to an existing system. The algorithms utilize a binary tree structure in conjunction with a database. Binary trees are extremely useful for representing a defined range of numbers which is further broken down into subsections of the over all space. These subsections draw a close parallel with the concept of network subnetting. IP subnetting examples are presented as introductory material then later are expanded to show how a binary tree can be represented in a database where upon IP address management queries can be extracted.

What is an IP Address and What is a Subnet?

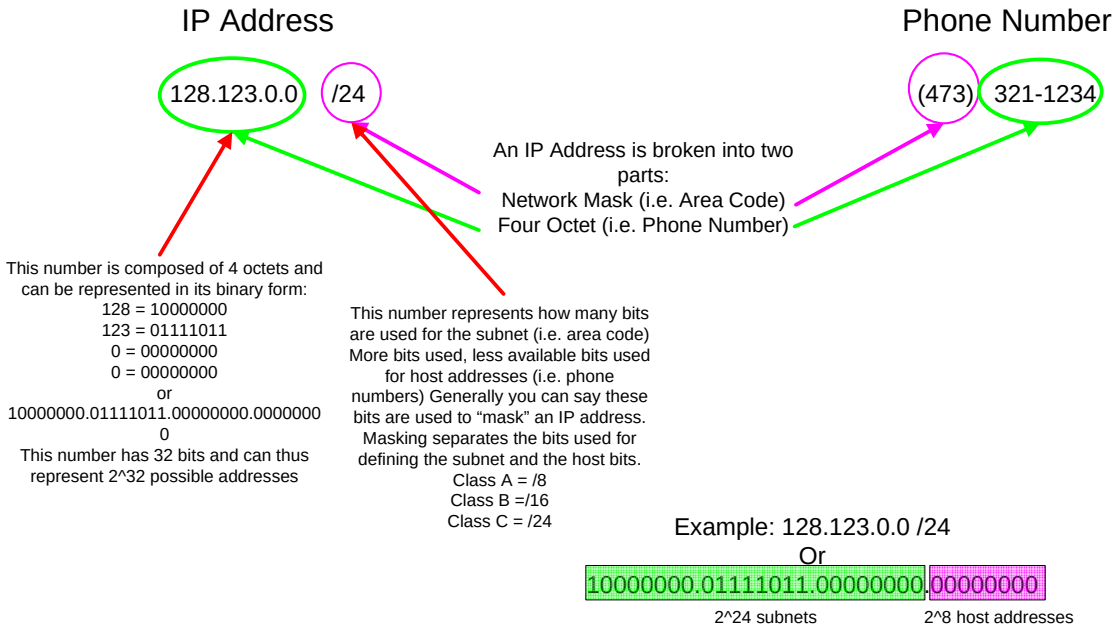


Figure 2 - Subnets and IP Addresses

Binary Trees and IP Address Space

The root of a binary tree is representative of a network class before it has been broken down into smaller subnets. In this example we will use a Class A network.

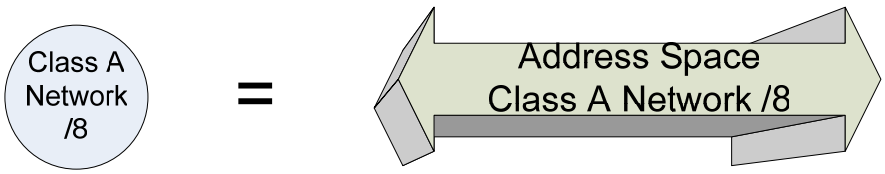


Figure 3 - Node and Address Space

Classic addressing usually involved 8-bits, 16-bits and 24-bits used to identify the network. These are called Class A, Class B, and Class C networks respectively. Any number of bits outside the standard class system used for masking an IP address (i.e. identifying a network) is called Variable Length Subnet Masking (VLSM). A node in a subnet tree may have two children at most. These

children represent the total address space of its respective parent. Children are created by increasing the bits used to define a subnet by one bit.

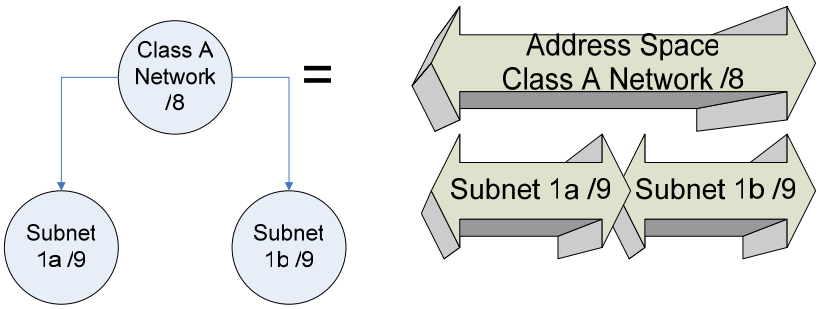


Figure 4 Node Division

As more bits are used, the binary tree's nodes are further broken down and Useful information and patterns start to reveal themselves.

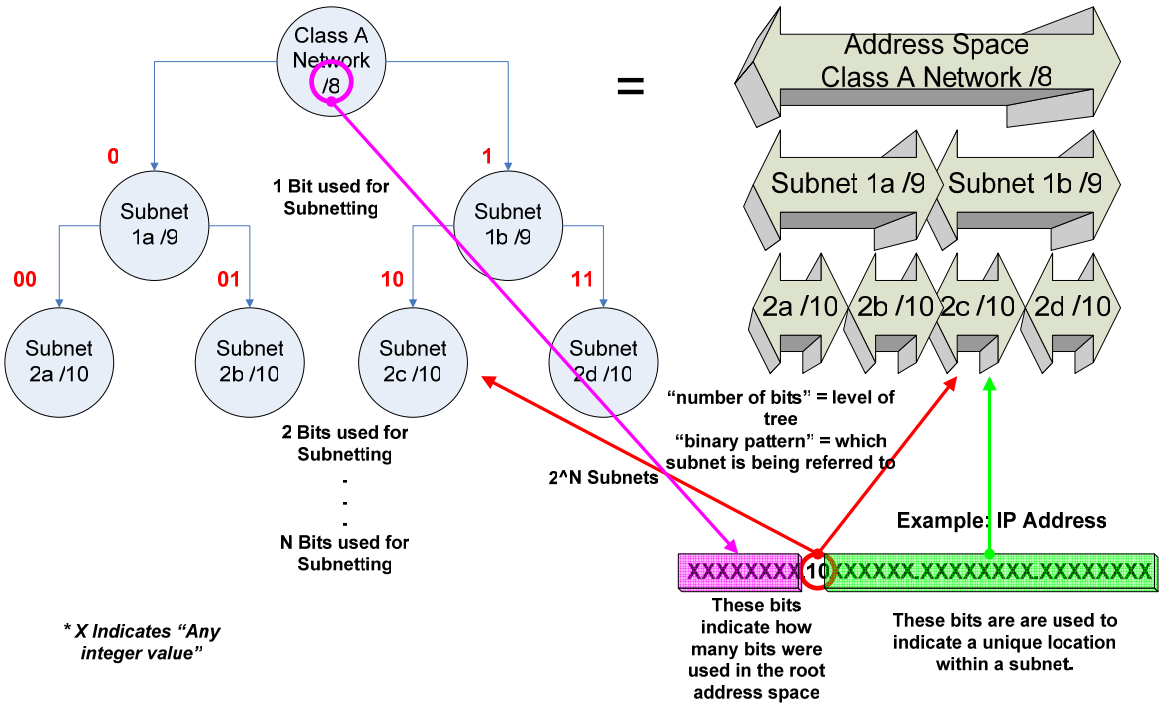


Figure 5 Node Relation to Address Space

Using a binary tree to visually represent how an address space is broken up makes it much easier to understand. To determine whether or not a subnet has already been assigned, it is only necessary look at the binary tree and check if the desired node exists. If the node exists, then the subnet is allocated or

partially allocated. A node with a child indicates that part of that address space has been taken and therefore the node may not be fully assigned. A node on a tree with no children indicates that nothing below that node has been allocated therefore that node may be allocated in its entirety. Below is a brief example.

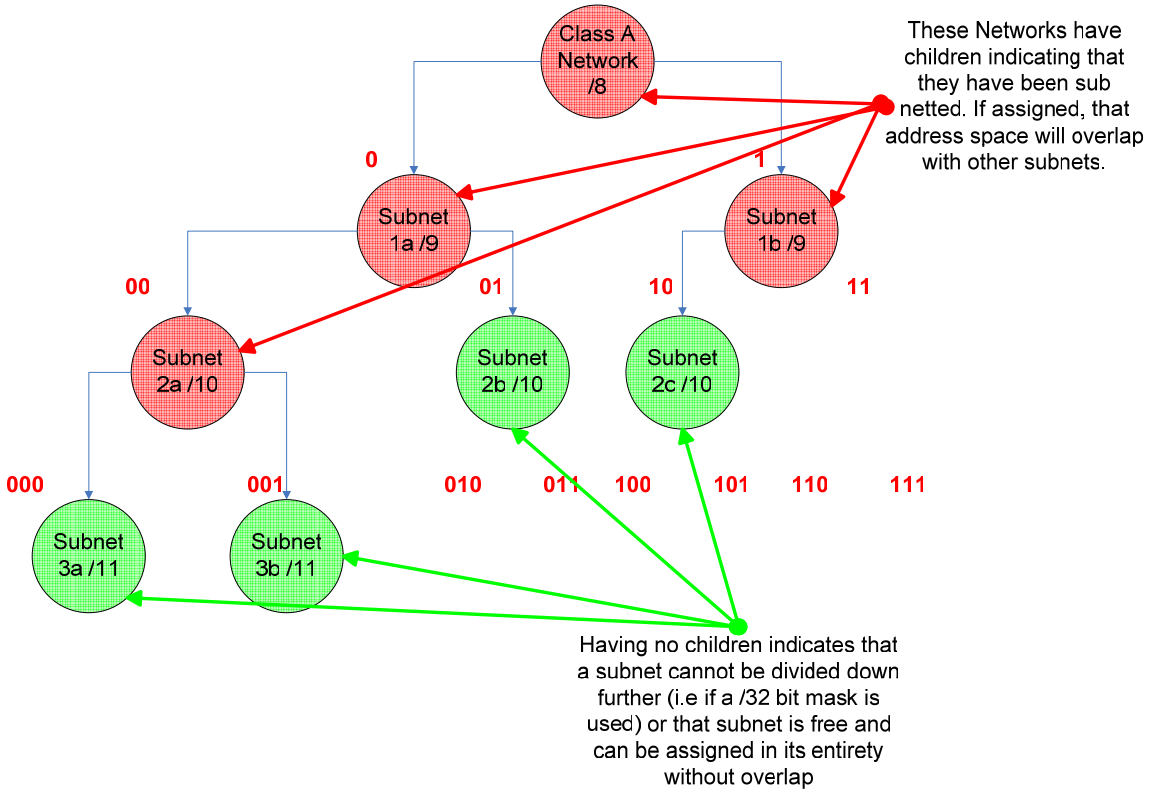


Figure 6 Subnets and Children

It is evident that a binary representation of an address space would be a beneficial concept to build an IP address management tool around. A numbering system of using upper and lower limits is required so a binary tree representation may easily be implemented in database form.

A subnet can be represented by creating two unique integer values representing the maximum and minimum limits of that address space. This is accomplished as follows:

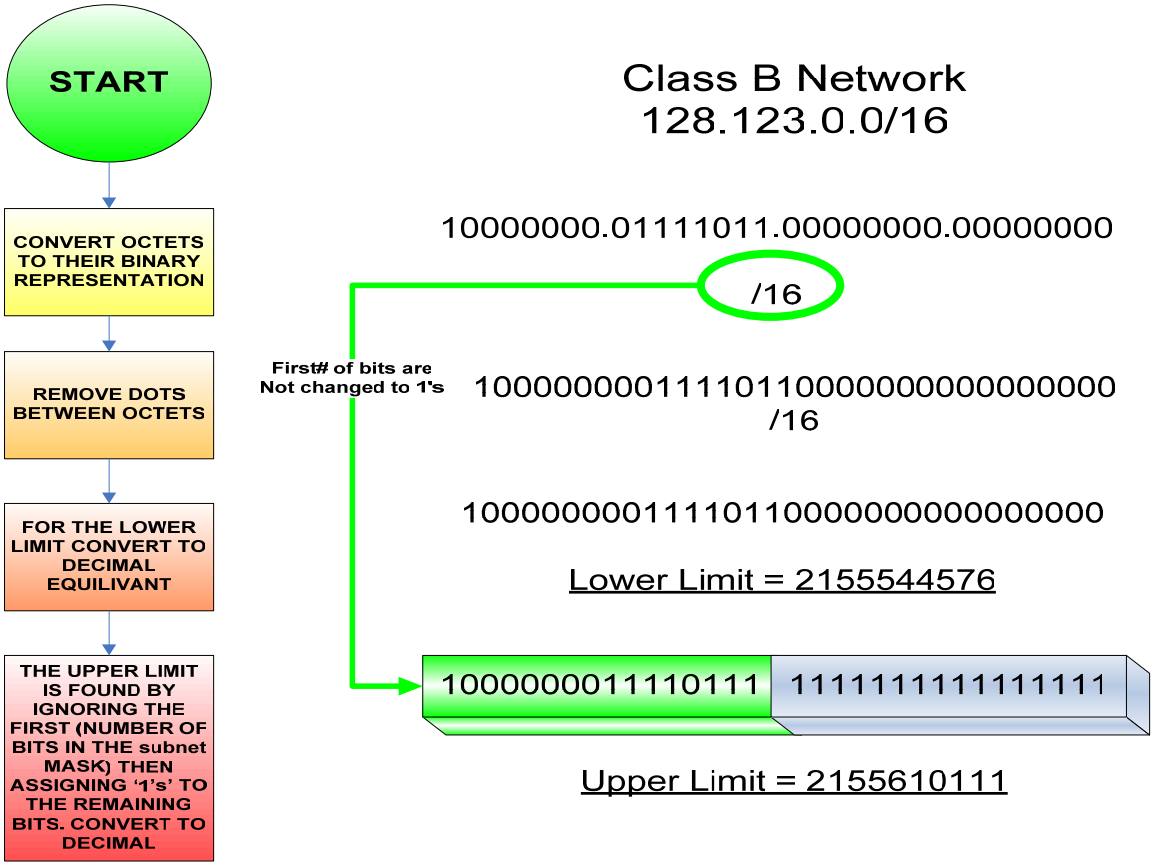
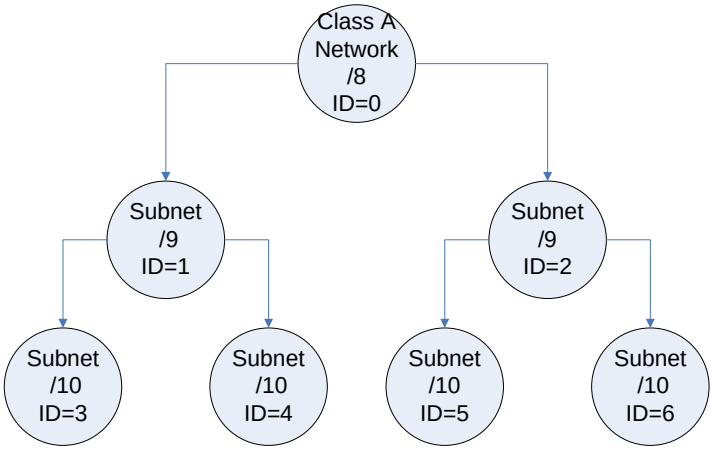


Figure 7 Upper and Lower Limits

Upper and lower limit values give means to establish the foundational work for database representation. The minimum requirement for a database to implement a binary subnet tree is to keep track of, parent and children nodes. One way this is executed is to assign each node a unique identification number. A child or parent of that node could then reference that identification number when necessary. Here is an example of what such a setup might look like.

Example: 128.123.0.0/16



Node ID Number	Child of Node	Lower Limit	Upper Limit	Bits Used for CIDR mask	Usage Description
0	0	2155544576	2155610111	8	This network is for Jo
1	0	2155544576	2155577343	9	Ted's Network - worki
2	0	2155577344	2155610111	9	John's Network - stud
3	1	2155544576	2155560959	10	N/A
4	1	2151522304	2155577343	10	N/A
5	2	2155577344	2155593727	10	N/A
6	2	2155593728	2155610111	10	N/A

Figure 8 Database Example

Now that the network binary tree is represented in a database form, algorithms can be constructed for IP address management. Below is an example algorithm that is used to assign a subnet.

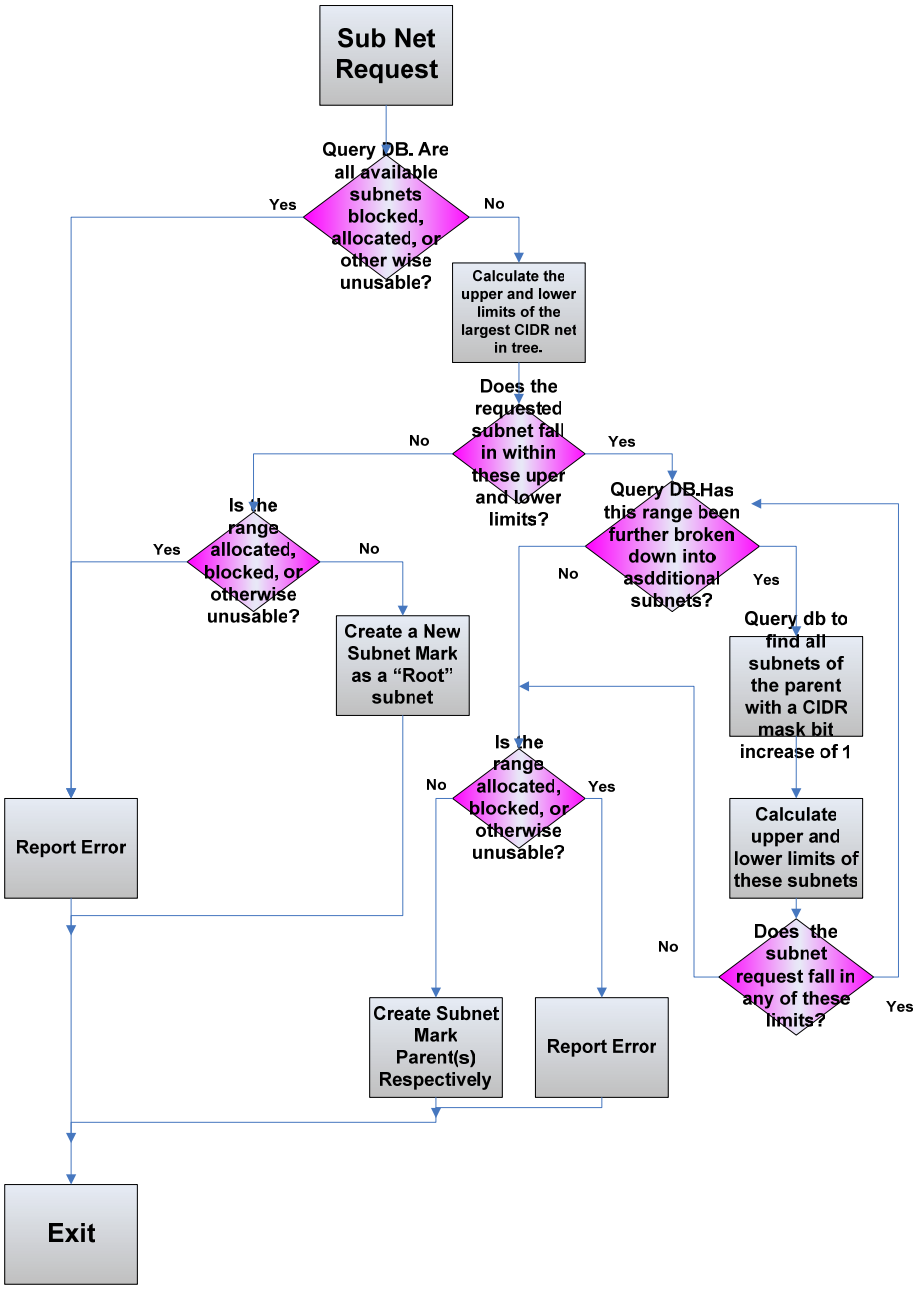


Figure 9 Subnet Request

Subnet binary trees are very beneficial to managing a subnet space. Further capabilities can be gained through adding fields to the data base and developing advanced algorithms of IP address space management.

Summary

Sandia National Laboratories network space is underutilized. SNL cannot justify a reason to obtain more address space from Internet Assigned Numbers Authority (IANA). So steps must me taken to increase IP address management capabilities at SNL. Open source tools can give key insights to principles that may be useful for further development and implementation in conjunction with the Network Information System (NWIS). Part of extending existing capabilities includes a management system to oversee the use of the IP address space. Binary tree structures, extracted from open source tools, draw a close parallel with network sub netting. These structures can be used to better manage an IP address space when combined with a database. Incorporating binary tree principles is feasible and will help SNL to better manage its IP address resources. The principles for managing an IP address space can be used both for IPv4 and IPv6.

Outlook/Implications

Integration of NorthStar or a binary tree algorithm, to improve SNL's IP address management, is feasible. Not only will it provide an effective IP address management system, it will also give SNL VLSM support. The practice of assigning Class C networks as the smallest available subnet can be ended. VLSM will help SNL to effectively manage its IP address by allocating enough IP address space to fit a customers needs. NorthStar doesn't have to be integrated in its entirety. The binary tree structure extracted from NorthStar can also serve as a means to improve IP address management. NorthStar will provide the foundation for future development.

Future Work

Future studies will consider alternate methods of address space representation and how legacy assignments can be defragmented to form a contiguous allocation of IP address space

Appendix A

IP Address Management: A Global Problem

IPv4 has been used for 20 years and is becoming inadequate for current IP address requirements. Despite using 32 bits for addressing and providing 2^32 addresses (i.e. 4.2 billion), the available address space in IPv4 is running out. When IPv4 was developed, some future growth was anticipated but not at the levels of today. There is evidence to believe that all existing addresses in IPv4 will be assigned by the year 2010 [3] and the need of more IP addresses will only increase.

As technology advances, so does the availability of electronic devices that have networking capabilities. It can no longer be said that computers are the only entities connected to the internet [4]. Now the list must also include: televisions, home stereos, personal digital assistants, gaming systems and cell phones. The list of devices with networking capabilities is being added to constantly while the rate at which IP addresses are being used is increasing exponentially.

The predicament of running out of IP address space is a global problem. East Asia is the first to feel the problem's effects in its entirety. It is estimated that by the year 2007 China's IP addresses space will be depleted [5]. When IPv4 was constructed 20 years go, 70% of all available address space was allocated for the U.S. and Europe and this has not been changed. The IP addressing needs of China is considerable. China was originally given 22 million IP addresses for a population of 1.3 billion people. In 2002 there were 17 million Internet subscribers, and the figure will hit 62.5 million in 2007 [5]. It can be argued that China's status is a direct result of rapid development, scarce initial IP allocation, and lack of dynamic global IP address management.

China and other East Asian countries have been at the forefront in the deployment of the new protocol known as IPv6. IPv6 utilizes 128 bits for

addressing which can support 2^128 or 3.4 x 10^38 possible IP addresses. IPv6 can address many of the limitations inherent [4] in IPv4, some of these include:

- ***Scalability*** – IPv6 offers far greater amounts of addressing space than IPv4
- ***Security*** - includes security features in the basic specification including encryption and authentication of packets (i.e. IPSEC)
- ***Real-time applications*** - IPv6 employs a mechanism that assists in routing these packets
- ***Plug and Play included in standard specification*** – useful for novices and portable computing devices
- ***Clearer specification and optimization of the protocol*** - good practices of IPv4 have been maintained, while inappropriate or outdated practices have been revised

The conversion to IPv6 noticeably increases available address space and extends routing capabilities [1 2]. Poor IP address allocation will negate any gains in address space if address allocation is improperly managed. The history of IPv4 shows this with the advent of using classes to break up an address space. Later it was found that class allocation led to considerable IP address waste. This was dealt with, in part, by variable length subnet masking (VLSM) among other techniques. Since IPv6 is such a new technology, now is an ideal time to perfect IP address management. It is essential that sound technical solutions and proper management practices are set forth before the switch to IPv6. Not only will the life of IPv4 be extended but many poor IP address management practices will not be carried over into IPv6.

Appendix B

Network Utilization

One of the forerunners that have been involved with IP address management at SNL is Mike Diehl. Mike has been working extensively on a set of tools that provide information about the networks at SNL. Some of these tools give indications that the attempts at IP address management are less than satisfactory.

Sandia Open Network (SON)

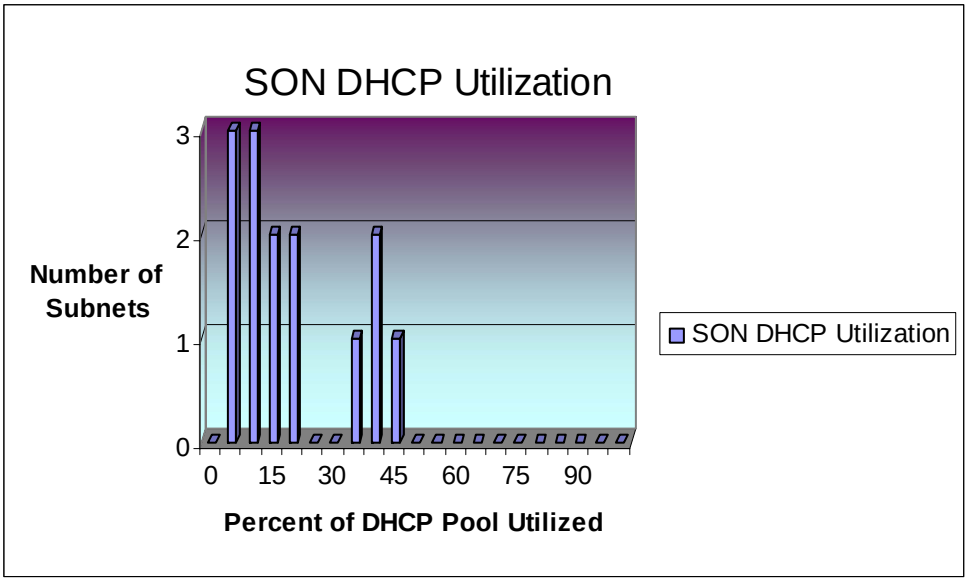


Figure 10 SON DHCP Utilization

The above figure shows that 100% of the SON networks have less than 50% DHCP utilization. Although having poor DHCP utilization is not a clear indicator of how well a subnet is utilized. The lack of DHCP utilization can raise suspicion. Using Mr. Diehl's tools we look at a three subnets with an increased granularity. It is evident that the trend of underutilized DHCP is generally indicative of an underutilized subnet. There are situations where this trend will not hold. See Figures below.

Figure 11 DHCP SON Example 1

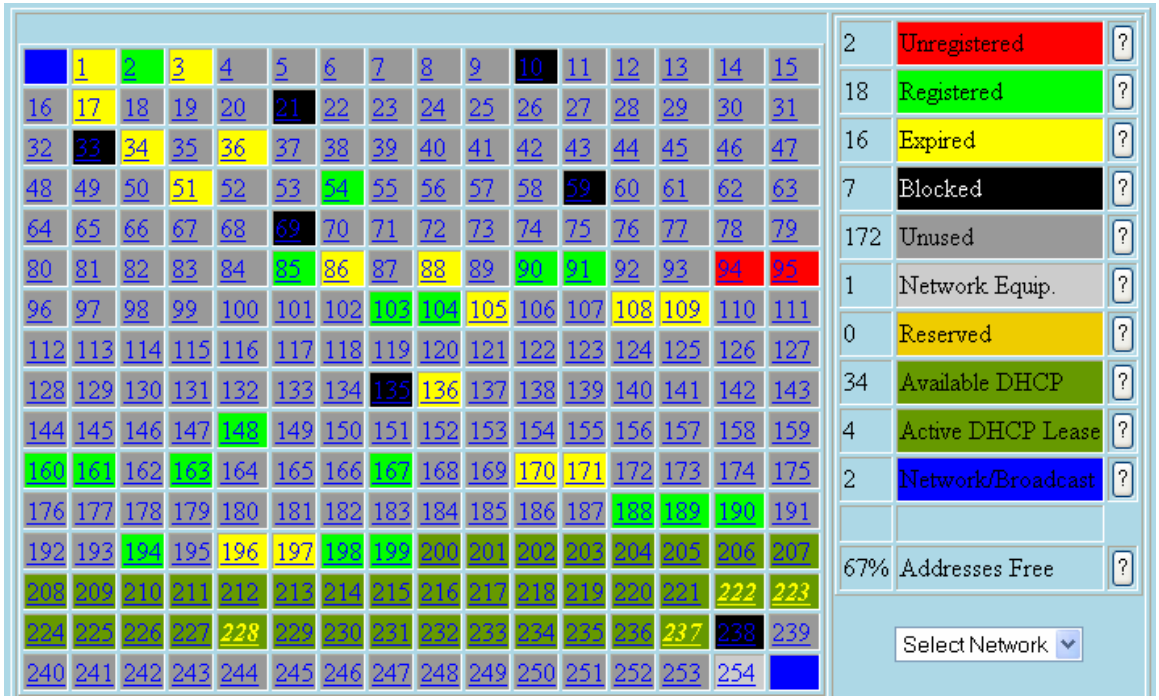


Figure 12 DHCP SON Example 2

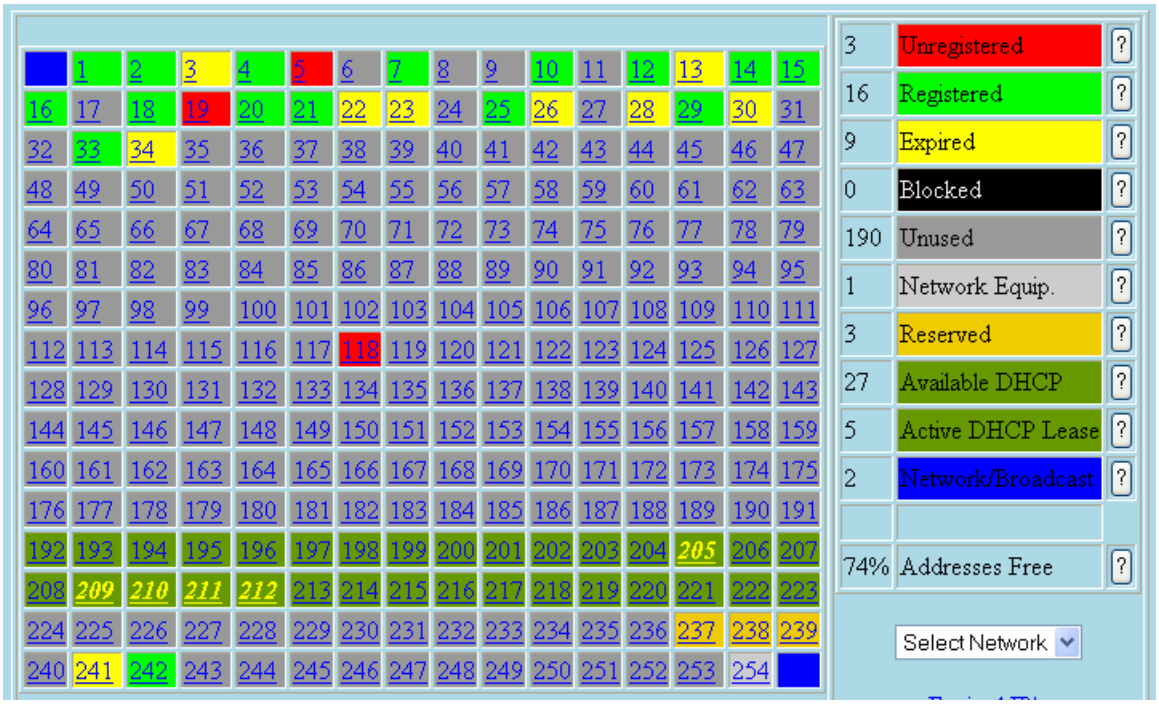


Figure 13 DHCP SON Example 3

Sandia Restricted Network (SRN)

The SRN has many more subnets than the SON and the nature of the work done there is vastly different. However 64% of 151 networks viewed on the SRN have less than 50% DHCP utilization. Once again the granularity is increased so the trend of underutilization of DHCP is indicative of an underutilized subnet can be seen again. See Figures below.

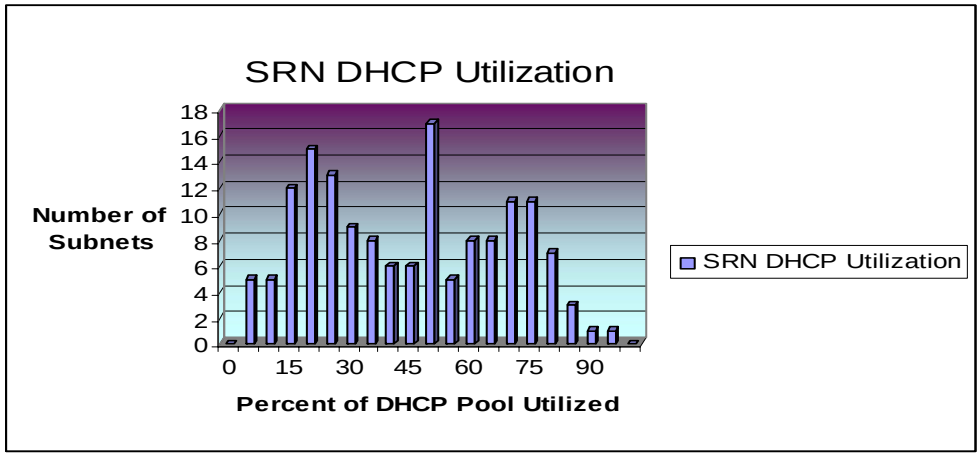


Figure 14 SRN DHCP Utilization

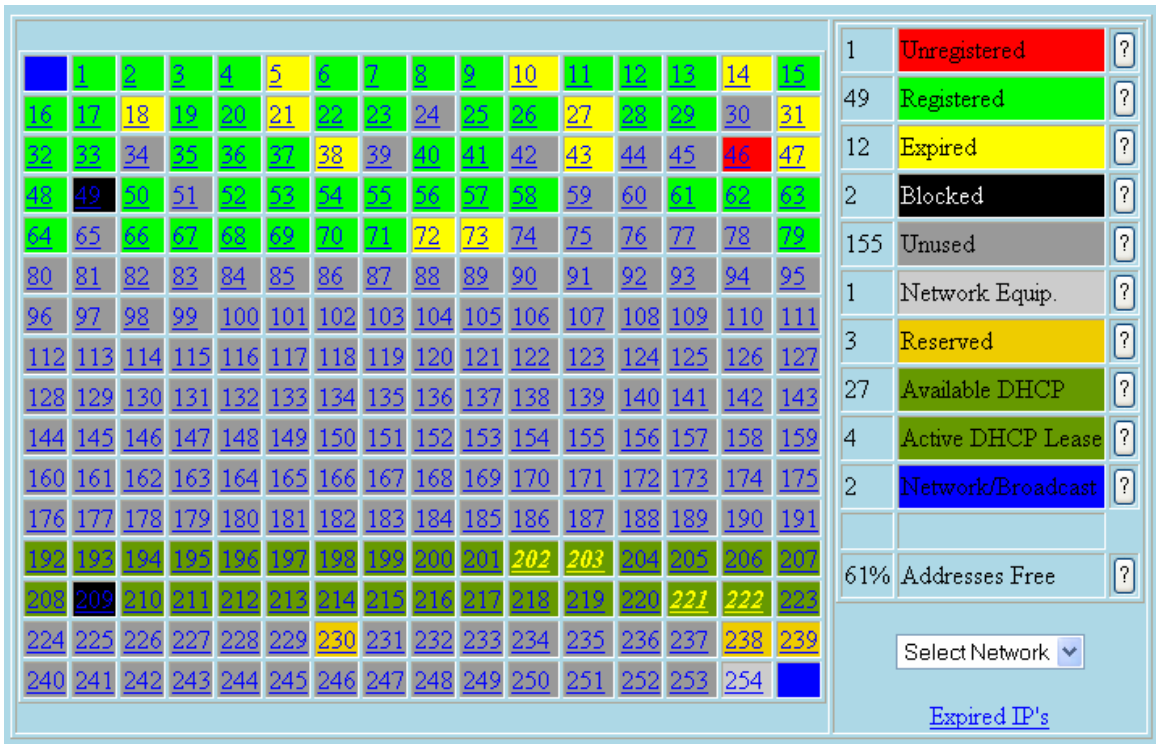


Figure 15 SRN DHCP Utilization Example 1

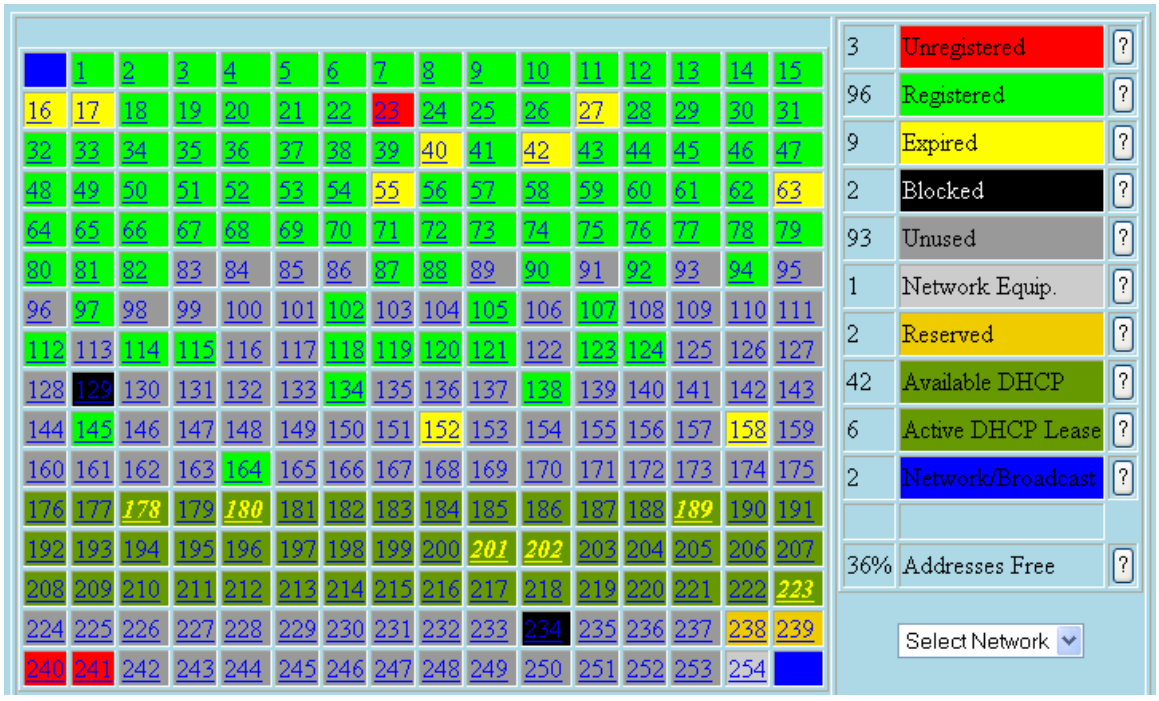


Figure 16 SRN DHCP Utilization Example 2

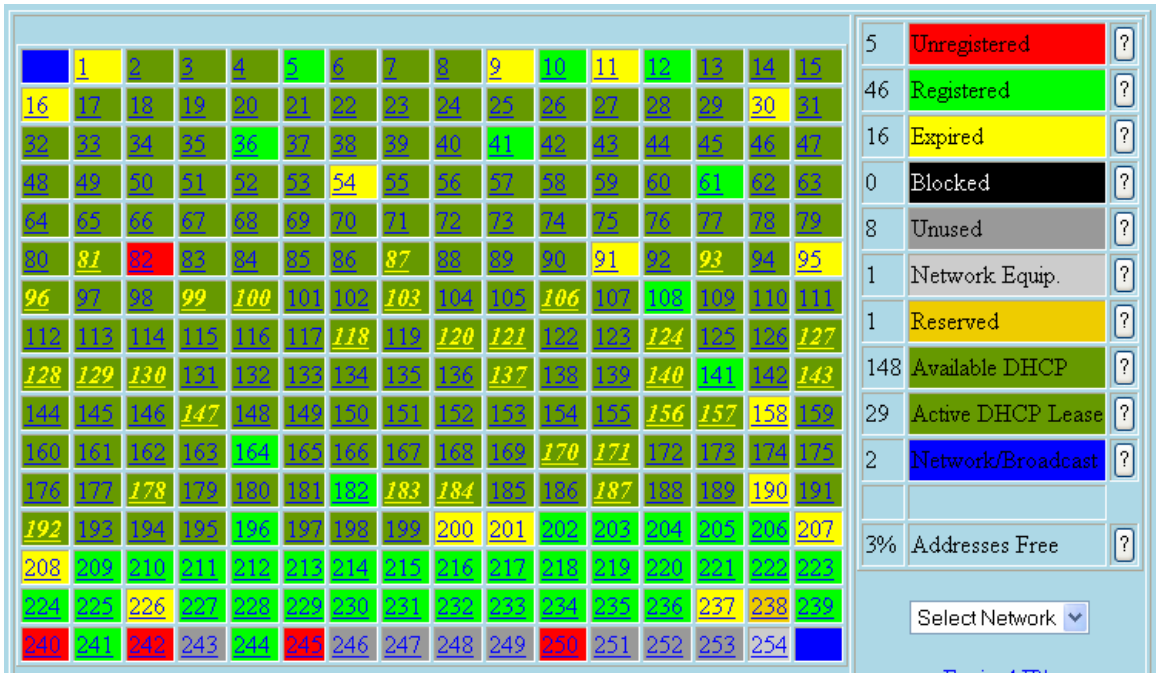


Figure 17 SRN DHCP Utilization Example 3

One can see by observation that under utilized DHCP usually occurs in association with an underutilized subnet at SNL. However this is not always the case. An explanation of having an underutilization of DHCP is that the address pool contains a large amount of static IP addresses as shown by the following two figures.

Figure 18 DHCP Explanation Example 1

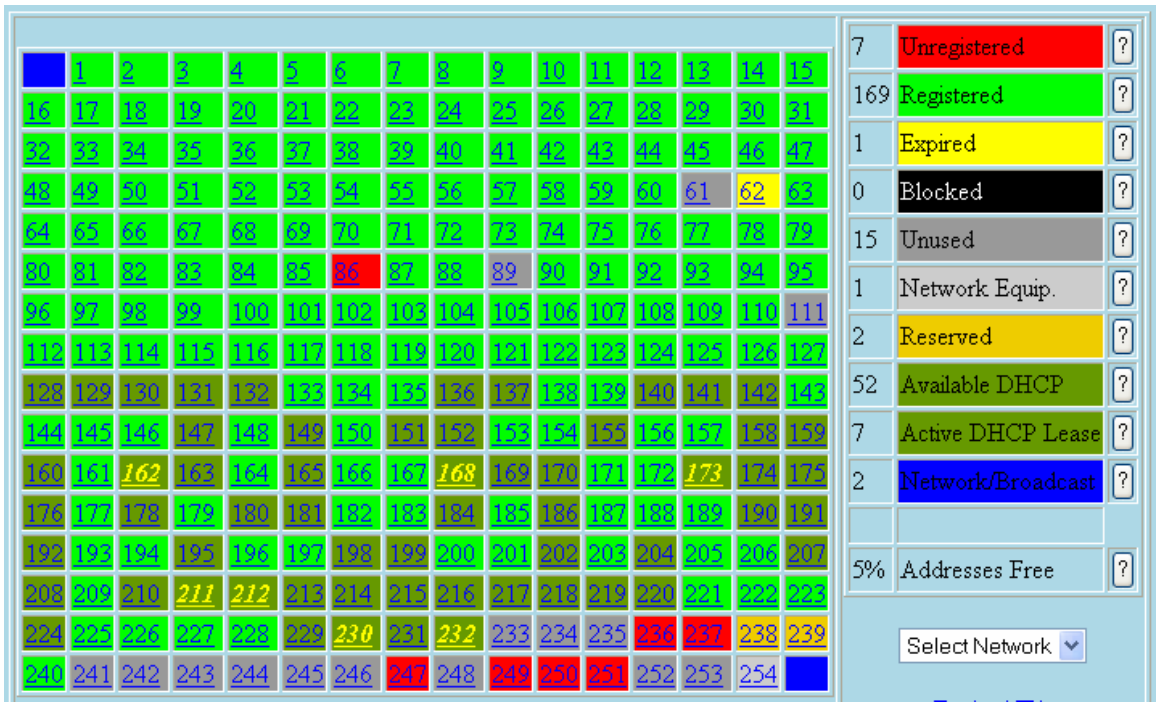


Figure 19 DHCP Explanation Example 2

Clearly there is an imbalance in the way the networks are divided at SNL. Some networks are so under populated that there is no justification to give them an entire Class C network. On the other hand, some of the subnets on the SRN should be expanded because they are running out of IP addresses. The only way the SNL's IP address space can be divided down to fit custom needs is to have a good IP address management entity.

Appendix C

Open Source Vs Proprietary Tools

Open source over proprietary tools were selected for this investigation because they were more flexible than proprietary tools. Code study of the selected open source applications [6 7 8] often gave considerable insight into algorithms employed. If an open source tool could not be fully integrated into the existing system then its extracted algorithms could give a greater understanding of how they might be implemented. The up front cost of utilizing the open source tools was minimal. The primary deterrence of using them was that there was no standard to which they were written. The open source tools studied were largely unsupported, not well written, and uncommented. Although utilization of the open source tools had many strikes against them, the likelihood that their algorithms could be extracted was high because of good reference material [9, 10, 11, 12, 13, 14, and 15]. Below are general considerations when deciding which route is most feasible.

Open Source vs. Proprietary Tools	
Open Source Tools	**Proprietary Tools**
Pros	**Pros**
Free initial cost	Usually supported
Potentially cost effective	Somewhat developed
Can be readily modified	**Cons**
Cons	May not entirelly meet imposed constraints
Usually unsupported or very limited support	May involve high initial costs
May not be well written and/or uncommente	No source code available unless more resources are gathered to obtain it

Figure 20 Open Source vs. Proprietary Tools

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